

A mobile data acquisition system

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A mobile data acquisition system

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ABSTRACT: A mobile data acquisition (MobiDAQ) was developed for the ATLAS central hadronic calorimeter (TileCal). MobiDAQ has been designed in order to test the functionalities of the TileCal front-end electronics and to acquire calibration data before the final back-end electronics were built and tested. MobiDAQ was also used to record the first cosmic ray events acquired by an ATLAS subdetector in the underground experimental area.

KEYWORDS: Front-end electronics for detector readout; Control and monitor systems online.

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1. Introduction

In March 2004 the first eight of sixty-four modules of the TileCal barrel cylinder were lowered into the experimental cavern and barrel modules were added on a regular base. At that time, both the final back-end TileCal electronics and the TileCal Low Voltage Power Supplies (LVPS) were not ready to be used. Thus there was a long time span with electronically fully-equipped TileCal modules in the ATLAS cavern without adequate readout and power systems installed.

The TileCal collaboration decided to exploit this time period by building a temporary data acquisition system which could check the integrity of the electronics and verify the functionalities of many TileCal modules together.

A very important issue for the commissioning of the detector was to test modules in a configuration as similar as possible to the final configuration in ATLAS. In this way problems could be found and solved at an early stage of the commissioning.

2. The tile calorimeter

The central part of the ATLAS hadronic calorimeter system [1] uses scintillating tiles as active material. The tiles are arranged in an iron structure, perpendicular to the beam axis. They are read out by two wave length shifting fibers (WLS), on either side of the tile. The WLS fibers are grouped together in order to reach the desired granularity and their signal is read by HAMAMATSU R7877 PMTs (an 8-stage version of the R5900 [2]) located on the front-end electronics.

The front-end electronics of each TileCal module are located on its external edge. Each module contains two so-called superdrawers. Each houses up to 48 PMT's and the associated analog and digital electronics. A sketch of the electronics can be found in figure 1. The signal from the PMT is collected on a 3-in-1 card [3], which shapes the pulse and then sends it to:

- The trigger summation cards (the adders), where the signals from a calorimeter tower are collected and summed up. The signal is then used for the trigger decision.
- The integrator. Each TileCal superdrawer is equipped with an integrator, which is used for calibration purposes and for minimum bias monitoring.
- Two different amplifiers whose relative gain is 64. The output of the amplifiers is then sent to the digitizer boards for digitization. In each superdrawer there are 8 digitizer boards. Each digitizer board provides a double sampling (one for each of the two gains) using two separate 10-bit fast ADCs. The sampled signal is then stored in the pipelines, waiting for the trigger decision.

The 3-in-1 card can also inject a known amount of charge in the TileCal electronics chain. This is the so-called CIS (Charge Injection System), and it has been designed for calibration purposes.

Once the trigger signal is received, the corresponding data are sent to the back-end electronics for further processing.

Two systems are used to communicate with TileCal: the Timing, Trigger and Control (TTC [4]) system and the CANbus [5]. The TTC is an optical signal transmission system used to distribute timing, trigger and control information (accepted triggers, event count, resets, configuration, test commands, etc.) to the front-end electronics. This information is sent by the LHC machine, the Level-1 Central Trigger Processor, the Data Acquisition System and the Detector Control System. There is a wide span of components that build the TTC system starting from the TTC-VMEbus interface module (TTCvi) and going via encoders (TTCex), transmitters and optical couplers (TTCoc) to receivers (TTCrx [6]). A similar optical system is used to read out the data from the pipelines once the trigger is received by the front-end electronics. The CANbus system is used for the communication with the integrator and with the High Voltage system. One CANbus daisy chain spans 16 superdrawers.

The total number of TileCal readout channel is about 10^4 . At present, TileCal is under commissioning in the ATLAS experimental cavern.

3. Requirements

Addressing all of the constraints presented above, a new test-bench was developed and named MobiDAQ [7] (*Mobile Data Acquisition system*). The two main tasks of MobiDAQ were:

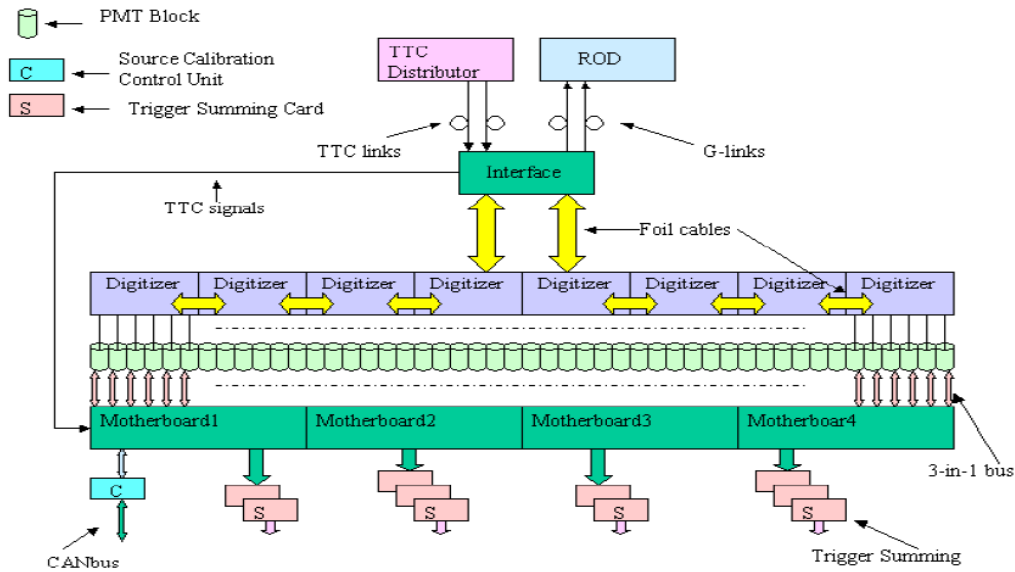


Figure 1. Sketch of the TileCal electronics (one superdrawer). In the figure, ROD (ReadOut Driver) indicates the back-end electronics system responsible for the data reading from the superdrawers.

- Running diagnostic tools for testing the TileCal electronics, cabling and connections.
- Performing real data acquisition (calibration, cosmic ray muons, etc.).

The system is designed to be an independent, mobile DAQ system for the simultaneous readout of up to eight superdrawers ($\sim 6\%$ of the TileCal barrel). The commissioning strategy of TileCal and the environment in the ATLAS cavern defined the main requirements of MobiDAQ.

- Mobility is essential for a temporary system which has no fixed place inside the cavern. It has to be possible to move it to different places without interfering with ongoing work.
- It has to be an independent DAQ system, parallel to the TileCal back-end. In this way we are not only able to start commissioning TileCal modules independently of other timescales but we also develop a system that can later cross-check the results from the TileCal back-end.
- The full readout chain has to be checked. The electronics has to be certified with cables of final length. The MobiDAQ system has to be able to test final services like cables, optical fibers, low voltage supplies, etc. as soon as they are available.
- The software developed for the new test-bench has to be based on the ATLAS DAQ software, allowing an easy integration in the final TileCal DAQ.

4. System setup

The main components of MobiDAQ are installed in a mobile rack, shown in figure 2. It houses a VME crate with different electronic boards (five single board PCs, one TTCvi, one TTCex, four

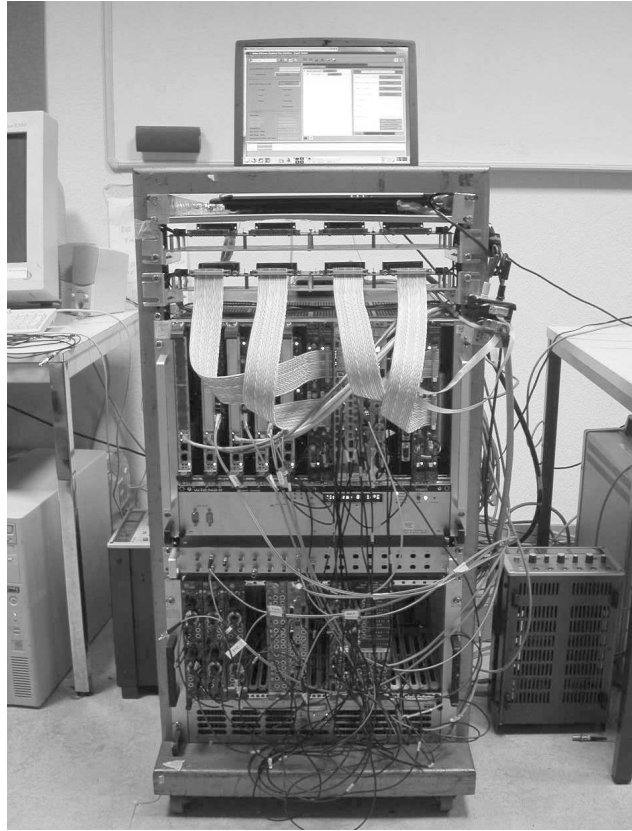


Figure 2. The MobiDAQ system. The mobile rack houses most of the components. The lowest crate in the rack is the NIM crate, which provides the trigger logic for the data acquisition. In the middle the VME crate is installed and in the upper part the custom trigger conversion boards are placed. The laptop, which is standing on the top of the rack, is used as the interface to the system.

Charge to Digital converter boards), a NIM crate, which provides the trigger for the data acquisition and custom trigger conversion boards. Other components like power supplies for the CANbus or for the TileCal superdrawers are either located close to the rack or close to the TileCal modules.

The schematic MobiDAQ layout is shown in figure 3. The data flow is indicated with the arrows. The G-Link and the Trigger cables are used for readout whereas the TTC fibers are used to send commands to the superdrawers. The CANbus is a special case because it works bi-directionally. Power supplies and the external interface are not included in the scheme.

4.1 MobiDAQ hardware components

MobiDAQ is based on VP110 [8] boards from the company Concurrent Technologies. They are VME processor boards, supporting a 800 MHz processor and a variety of interfaces including an option for an on-board hard disk drive. In total five VP110 boards are used, one equipped with a hard disk and used to control the other four boards and to store the processed data. The function

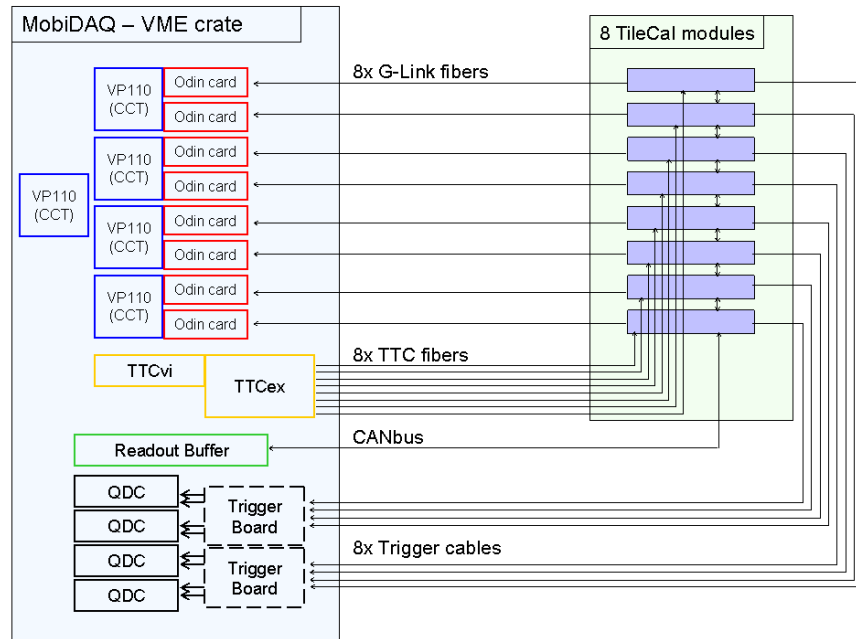


Figure 3. The layout of the MobiDAQ system. The schematic view shows how the system was interconnected with the TileCal superdrawers.

of the other four boards is to gather and process the digitized data from the superdrawers. All five VP110 boards are installed inside a VME crate and connected via Ethernet cables to a network HUB for communication.

4.1.1 Digital readout

The digitized data from the superdrawer are sent via the G-LINK optical fibers to the VP110 board, which is equipped with two ODIN cards (Optical Dual G-Link S-LINK interface) each in order to receive the information.

The S-LINK is a simple data link which is based on the S-LINK specifications defined at CERN [9]. It is used to connect the front-end electronics to the next layer of readout electronics. In addition it also includes error detection, self-test functionality and a return channel for flow control and for return line signals.

The ODIN card [10] is a standard S-LINK implementation. It uses optical transceivers with duplex LC connectors for the optical transmission. The SSP card is a PCI mezzanine card which is used as an interface between S-LINK Destination Cards (in the MobiDAQ case ODIN cards) and a PMC environment (in the MobiDAQ case the VP110 boards).

The firmware of the ODIN card has been modified to include CRC checking. An overflow protection is implemented to allow high rate triggering of the drawer (see section 5.1). Events are randomly sampled at a lower rate consistent with the processing speed available. This allows testing of the drawer at the ATLAS maximum trigger rate of about 100 kHz.

The data coming from the front-end electronics via S-LINK are then processed on the VP110 board and finally stored on the hard disk.

4.1.2 Analog readout

Four analog-to-digital charge converters¹ (QDC) are used for the readout of the analog signals from the adders. A trigger conversion card was developed to adapt the differential signal from the adders to the format and dynamic range of the QDCs.

4.1.3 Communication

As in the final TileCal setup, two systems are used to communicate with the superdrawer: the TTC and the CANbus systems.

In the VME crate a TTCvi and a TTCex module are installed. The TTCvi, configurable through VP110, sends signals to the TTCex, which converts the electrical signals into laser pulses. One of the ten optical outputs of the TTCex is used and connected via an optical fiber to an optical splitter (TTCoc in the following). Eight optical duplex fibers (TTC fibers) fan out from the TTCoc and distribute the signals to the eight connected superdrawers.

To perform the readout and control the integrator ADC of many superdrawers connected via several CANbus daisy chains, MobiDAQ was equipped with a Quadruple VME CANbus controller [11], the Readout Buffer. It is controlled by the VP110 boards. The Readout Buffer is specially developed for the readout of TileCal. Its use in MobiDAQ made it possible to evaluate it in a real working environment and to give suggestions for improvements.

In addition to the readout of the integrator ADC, the ADC CANbus-Readout-Buffer chain is used as an alternate path to send commands to the 3in1 cards and provides the only path to read back settings from the 3in1 cards. As opposed to ATLAS, in MobiDAQ two of the four Readout Buffer ports are used to control the HV CANbus (sending commands to the HV micro cards and reading settings and values of the HV micro cards).

4.1.4 The trigger system

The trigger system of MobiDAQ is built with several NIM electronic modules (1). The modules are situated in the NIM crate below the VME crate. The purpose of the logic is to provide the trigger signal (analogous to the ATLAS level 1 acceptance trigger signal) to the readout and issue “busy” signals, in order to disable the trigger while reading out the VME modules.

4.2 External components

Aside from the mobile rack there are several external components of the MobiDAQ system:

- User interface: although the VP110 boards can be used as an autonomous computer, a laptop or a PC is used as a user interface. It is connected to the network HUB via an Ethernet cable and the user can log in to all five VP110 boards if necessary. Nevertheless the processing of the data is all done on the boards themselves. By connecting the network HUB to an external network it is also possible to control MobiDAQ from any other computer terminal.

¹Reference: CAEN QDC, Model V792



Figure 4. One of the temporary low voltage power supplies which power the electronics of the TileCal module.

- CANbus power supply: close to the mobile rack there is a standard power supply to power the CANbus. It provides the 12 V for both CANbus lines.
- High voltage power supply: one of the final TileCal HV power supplies is used to power the superdrawers.
- Temporary low voltage power supplies (LVPS): commercial LVPS ² are used to power the front-end electronics. Their small size ($20 \times 25 \times 7$ cm) permits mounting them directly on the TileCal fingers with specially designed aluminum plates as shown in figure 4. This minimizes the impact of the MobiDAQ tests on the working environment close to the detector.
- Temporary cabling: eight full sets of temporary cables are routed from MobiDAQ to the TileCal modules. They are chosen to match the real ATLAS cable length, both on A and C side. A set of cables includes the following parts:
 - TTC fiber
 - G-Link fiber
 - Trigger cable
 - Laser fiber
 - HV cable
 - CANbus cable

Only one CANbus cable is needed for the eight superdrawers since they are connected to each other via a CANbus daisy chain.

²Reference: Power-One Model ESP6C212265-00

- **Cooling:** to ensure stable running conditions the front-end electronics have to be cooled. This is done with demineralized water at 18°C. Two TileCal prototype cooling units are used; both of them work with a 'Leak-less Cooling System' [12].

The MobiDAQ rack, the laptop, the CANbus power supply and the HV power supply are all located inside the cavern, USA15. This cavern is separated by a 2 m concrete wall from the main cavern, UX15, where the ATLAS detector is installed. USA15 is equipped with many rows of racks to provide space for all the back-end electronics of the ATLAS subdetectors.

The temporary LVPS are located in UX15, attached to the fingers of the TileCal modules. Also the prototype cooling units are located in UX15, close to the detector.

5. MobiDAQ software

The software for MobiDAQ is based on several sources:

- The environment and libraries provided by the ATLAS Trigger and DAQ group [13].
- Readout libraries and test software developed in former test-beams.
- Test software used during the construction phase of the calorimeter.

In order to achieve the goals of MobiDAQ, not only significant changes and upgrades of the existing software were necessary but also new code had to be developed. Libraries to access the VME modules, tests to perform detailed checks of the electronics, and the control of the parallel tests to prevent conflicts during data acquisition were the most significant pieces of code developed.

5.1 Diagnostic tests

The task of the diagnostic tests is to check very specific functionalities of a component or a set of components of the front-end electronics. The tests can be run in command-line mode or via the automation system (see section 5.2).

At the end of a test the result is displayed, which is either "success" or "failure". Additional error messages give hints about the type of problem that occurred. In the more sophisticated tests raw data or plots are saved into files for further analysis.

The tests are described in detail below.

ADC CANbus. The communication with the integrator ADC via CANbus is tested by retrieving the version number of its firmware. When the version number is received successfully the connection is considered to be working.

TTC connection. This test checks the communication with the 3-in-1 cards via the optical TTC fibers. The bits of the 3-in-1 card are flipped in a distinct order and read back to verify the connection and the functionality of the cards.

BCID (Bunch Crossing Identifier) test. The analog signal from the 48 channels of one TileCal superdrawer is digitized in 8 digitizer boards, which house the 10-bit fast ADC. Each digitizer board contains two custom chips (TileDMU) that collect the information from 3 channels. Each TileDMU sends a BCID number with every event. The consistency of the BCID numbers all along the superdrawer is checked: they have to be identical for all TileDMUs.

CRC (Cyclic Redundancy Check) test. The electronics in the superdrawer calculate a check sum using a specified formula and the measured data. The same procedure is performed outside the superdrawer with the received data and the two numbers are compared. If they are identical the transmission of the data was successful.

Test of the Integrator readout chain. This test checks the functionality of the Integrator ADC and its communication with the back-end electronics. For each PMT channel, it additionally checks the level of the pedestal and its RMS, the switching between the six integrator gains and the linearity of the signal. For this purpose the test is separated into two parts:

- *The Integrator ADC test* verifies the basic functionalities of the integrator ADC and the connection with the back-end via CANbus. A successful result in this test is essential to be able to continue with the second test. In several steps the following points are verified:
 - The initialization procedure.
 - The configuration of subtracted pedestal and delay.
 - The configuration of the 3-in-1 cards via CANbus.
 - The configuration and performance of the automated scan (calibration and gain test).
 - The performance of the fast ADC conversion for the minimum bias readout.
- *The Integrator gains test* checks the calibration of the six integrator gains. For this purpose a DAC ramp is performed for each gain in its appropriate range and the ADC counts are measured. For each measurement the average ratio between DAC value and measured ADC counts of 100 events is computed. The gains are calculated by a linear fit of the ratio. The resulting gain and the linearity of the fit are required to correspond to the range measured with a set of well-performing reference superdrawers.

Additional tests, based on a data sample with 100 events, measure the pedestal and the pedestal noise for each channel and each gain. The pedestal noise is required to be low enough to allow a minimum bias monitoring in all cells. In order to ensure the selection of the correct card, an additional test injects different charges for even and odd channels and measures the response of each channel.

The results of the integrator gains test for gain-5 are shown in figure 5 for one representative superdrawer. For each channel the fitted gain, the χ^2 of the fit, the pedestal and the pedestal noise are plotted. The red lines indicate acceptable values for a standard TileCal superdrawer.

Register test. In the superdrawer a number of registers can be changed via TTC commands. This test verifies the ability to modify their settings.

The following registers are verified by the test:

- Motherboard time: One register exists per motherboard. It controls the time of the charge injection with respect to the arrival of the TTC command.
- DSkew time: One of the two fine DSkew registers of the TTCrx on the digitizer controls the phase between the ADC sampling and the 25 ns clock.

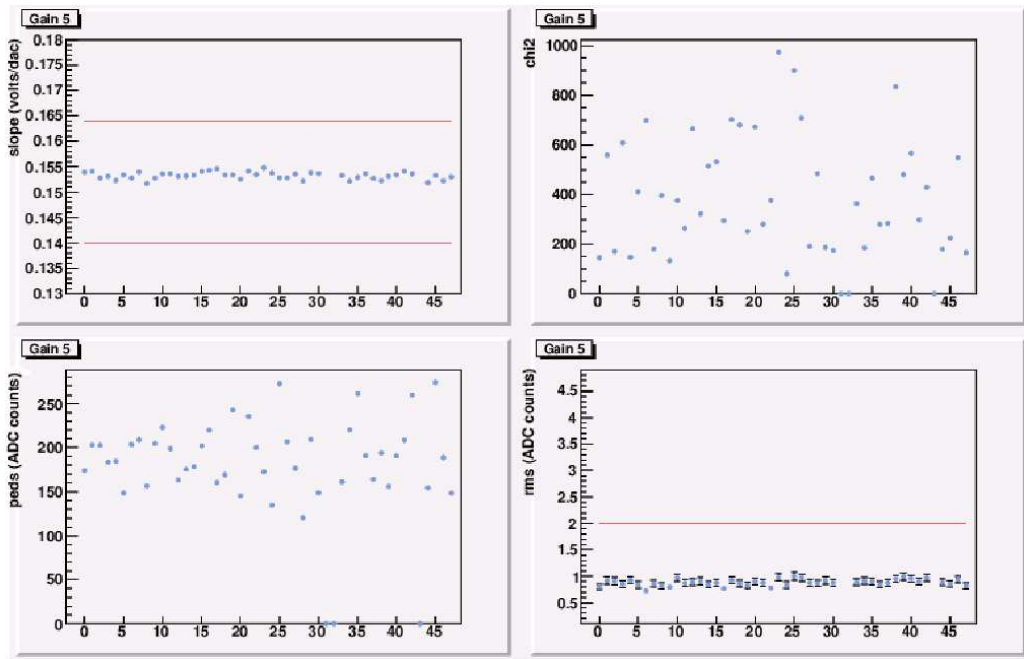


Figure 5. An example of the result display for the integrator gains test.

- Pipeline length: a register controls the pipeline length, which is the time between the physics signal and the arrival of the trigger signal to the front-end electronics.
- Pedestal level: One register per digitizer controls the pedestal level.
- Capacitor and DAC level for the 3-in-1 cards: It controls which one of the two capacitors and which charge is used for the charge injection.

The test is started on one superdrawer at a time. After reading the test settings from the configuration database, five charge injection events are acquired. The average time and amplitude of the signal are computed. Then the motherboard times are changed by 30 ns, and five more events are acquired. The new averaged value for the time is compared to the old one, channel by channel. The test fails if the time difference for any channel deviates from the expected result. The same technique is used for the DSkew time and for the pipeline length.

For the pedestal level, five pedestal events are read out and the samples are integrated. The pedestal is subsequently increased and another five events are read out. The difference between the average results of the integrals is then verified.

The last step is to inject predefined charges and to verify the resulting amplitude of the readout signal.

If any of the changes fails for any of the channels, the whole test fails.

Noise test. The electronic noise is one of the most important parameters of the detector. It can be different for every channel, depending on the electronic cards and their activity and it can even vary in time.

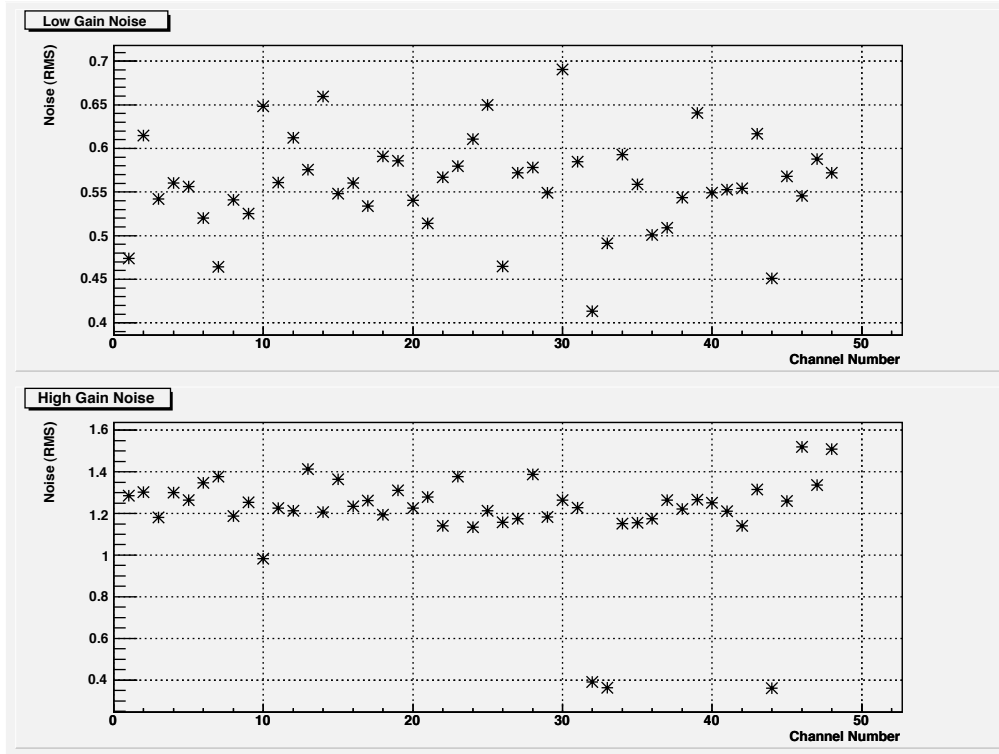


Figure 6. A typical result from the noise test. The RMS pedestal noise (in ADC counts) of all channels of superdrawer LBA47 in the low and the high gain readout is shown.

Significant effort was invested into keeping the noise level in TileCal close to the design expectations.

For the noise test, 1000 pedestal events are taken. Seven digitized samples are read out in both gains from each channel. The noise is then calculated as the RMS of the seven samples and the average RMS over many events is computed. A typical result can be seen in figure 6. The pedestal noise of all channels in one representative superdrawer for the low and the high gain is shown. The values are consistent with what expected for a standard TileCal superdrawer. The channels 32, 33 and 44 are not instrumented with PMTs and therefore show lower values.

The noise test can be performed also at a 100 kHz rate in combination with the BCID and CRC tests. This allows the cross check of the data taking stability at high frequency.

Charge injection test. The charge injection test makes use of the CIS (Charge Injection System). Two capacitors on the 3-in-1 card are used to inject well defined charges into all the readout channels. This charge simulates a signal from the photomultiplier and is digitized and read out by the electronics through the same chain as a particle signal.

For the test two different charges are injected, 5 pC for the high gain and 600 pC for the low gain. A Gaussian is fitted to the measured pulse and the amplitude is evaluated. Then this amplitude is compared with values from reference superdrawers.

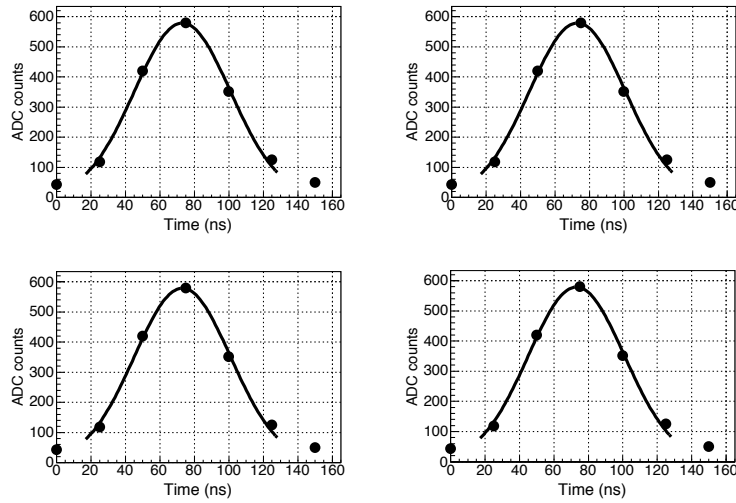


Figure 7. A typical output of the charge injection test. The pulse in four channels is shown. A Gaussian is fitted to the seven digitized samples.

A typical output from a successful test can be seen in figure 7. The CIS pulse in four channels is shown. The plot shows the value of the ADC reading as a function of time (ns). The gaussian fit to the pulse shape is also shown. The amplitude, the mean value, the sigma and the χ^2 of the fit are consistent with what expected for a standard TileCal superdrawer.

High Voltage system. A high voltage control program was developed based on the Readout Buffer and the CANbus connection to the superdrawer. The readout via the Readout Buffer is a MobiDAQ-specific feature. In ATLAS a dedicated CANbus controller currently being developed will be used. The HV control program provides all of the basic functionalities to control and read out the high voltage parameters:

- to set and read the voltages applied on the PMTs,
- to read the temperature probes located inside the superdrawer,
- to read the input voltages from the low voltage power supply,
- to set the CANbus node numbers for the superdrawers (used for identification inside a CANbus branch).

In addition, the test provides a continuous monitoring of the voltages by periodically saving the values to files for further analysis.

Trigger. There are two separate trigger outputs: the hadron trigger and the muon trigger. The former provides the analog sum of the analog signals coming from the TileCal pseudo-projective towers, the latter the signal from the cells of the outer longitudinal TileCal sampling. The objective of this test is to check that the LVL1 trigger chain is working properly. This chain is composed of

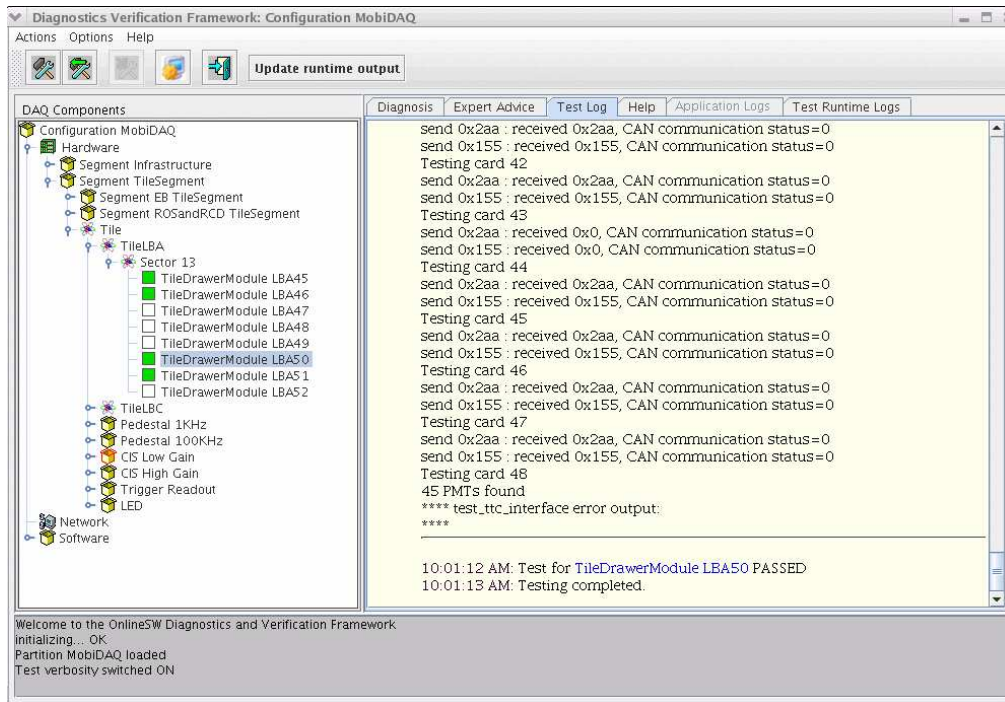


Figure 8. The user interface of the Diagnostic Verification System of MobiDAQ.

the 3-in-1 cards, the adders, and cables (internal and external). The signal is integrated and read out by the QDCs.

- *The hadron output test* checks the output of all adders present in the superdrawer. First it is checked if it is possible to enable and disable the trigger output of the 3-in-1 card. After that three different charges (70, 140, and 210 pC) are injected into each readout channel. A linear fit is applied to the measured ADC counts. If the fit is within a tolerance of 3%, the output is accepted as being linear.
- *The muon output test* ensures that the muon output of the adders is working correctly. This is accomplished by injecting a fixed charge of 7 pC and verifying that the output signal equals the value from a reference superdrawer within a 5% tolerance.

5.2 Automation of the test procedure

In order to be able to perform the diagnostic tests in a fast and user-friendly manner, we made use of a graphical user interface based on Java, the Diagnostic Verification System (DVS) [14]. Developed for the TDAQ [15] certification, it is capable of starting, synchronizing and controlling different processes. A few modifications permitted the use of DVS as a framework to control the TileCal diagnostic tests.

DVS uses the TDAQ configuration database, which stores all the necessary information about subdetector components needed for the configuration and data acquisition. For MobiDAQ the data

base additionally defines if a test can be performed in parallel on several superdrawers or only on one at a time.

The diagnostic tests are arranged in hierarchical order. Therefore the simple tests, e.g. the verification of the communication with the superdrawers, are performed first and eventually, in case all the previous tests are successful, the more sophisticated tests are started. DVS controls this sequence and provides information about the test result to the user. In case of failure an additional error output is displayed. An example of the user interface is shown in figure 8. On the left side a list of connected superdrawers can be seen. Some of them were tested successfully, which is indicated by the green square in front of the superdrawer name. The right side shows the log file of the last performed test with detailed information about the test status.

It is not mandatory to run the full chain of tests on all superdrawers. A test of interest can be chosen and started for a specific superdrawer, an essential feature in case of errors and during the detailed investigation of problems.

The implementation of the diagnostic tests into DVS is an essential step since this facilitates the integration into the final DAQ system of TileCal.

5.3 Performance of the diagnostic tests

The diagnostic tests implemented in MobiDAQ are meant to provide a fast response about the superdrawer functionalities. They have been developed for the commissioning, but they will be maintained also for ATLAS as a fast (and reliable) tool to verify the front-end electronics.

The time needed to perform a complete check of 8 TileCal superdrawers is about 5 minutes. Tests involving the CANbus system (which is intrinsically slower than the TTC system and which allow the test of only one channel at a time) are typically much longer than the tests of the digital readout (noise, charge injection, registers). The complete test of the digital readout alone takes less than 1 minute.

6. Data taking with MobiDAQ

With the TDAQ software installed on MobiDAQ it is possible to take calibration runs, i.e., data acquisition runs using the ATLAS official data acquisition software infrastructure. They closely imitate real ATLAS runs, although they contain pedestals, signals coming from the TileCal charge injection system, or signals coming from light injected on the PMTs surface using a LED system.

While the tests described above are meant to be used as a fast debugging tool for the calorimeter, these runs are used both to monitor its long term stability and to compute the calibration constants for the electronics. The data are stored in raw data files and have to be reconstructed and analyzed offline.

6.1 Performance

The MobiDAQ data taking is usually done with a trigger rate of 1 kHz. The typical size of one event in one superdrawer is about 1 kB. This means that the typical amount of data written on the disk is 8 MByte/s. One calibration run usually consist of 10000 events.

The total amount of data stored during the commissioning phase with MobiDAQ is about 200 GB.

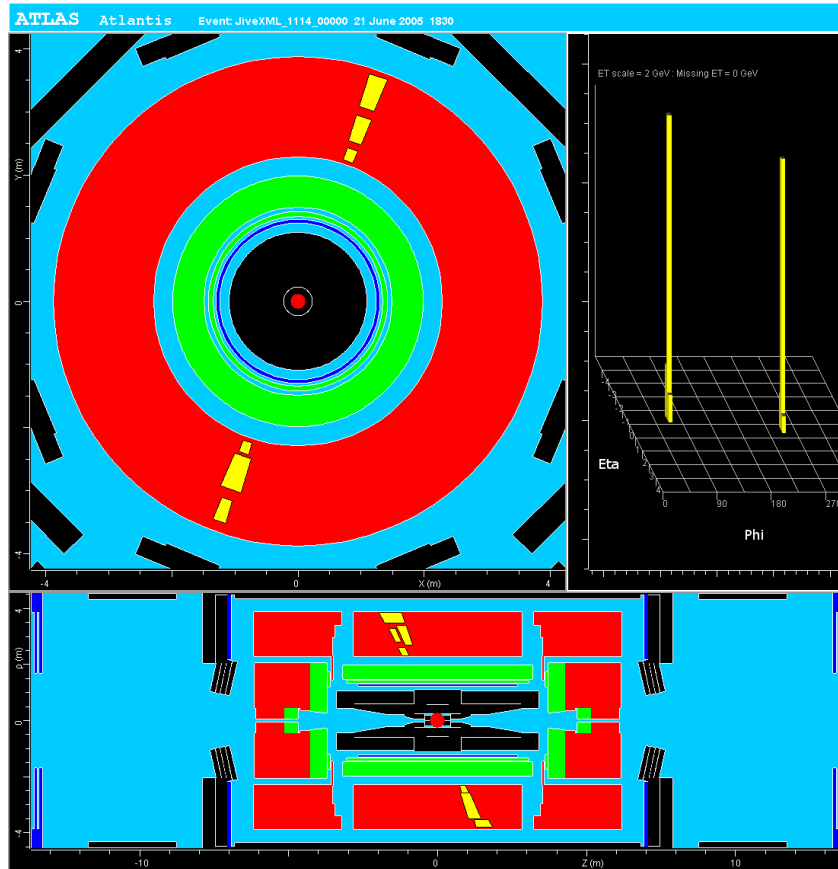


Figure 9. A view of a cosmic muon (yellow) crossing the TileCalorimeter (red).

6.2 Data taking with cosmic rays

In June 2005 a milestone for TileCal (and ATLAS) was reached: cosmic muons were recorded in the ATLAS cavern using TileCal and the MobiDAQ readout. This was the first time that a LHC subdetector, in its final position, recorded a particle [16].

The trigger was obtained asking the coincidence of a signal above threshold in a back-to-back pair of TileCal towers. A specific programmable board which receives the signals from the calorimeter and checks the coincidence of the towers has been designed and built.

Figure 9 shows a view of one of the few thousands cosmic muons recorded. The yellow regions indicate a high energy deposit. The most probable value of the energy released in a TileCal module by a projective muon (with respect to the interaction point) is about 2.5 GeV. That has to be compared with an average noise RMS per tower of about 50-60 MeV. Figure 10 shows the energy spectrum in the two most energetic adjacent towers in a TileCal module. The histogram has been fitted with a convolution of a Landau with a Gaussian function. The choice of the fitting function has been driven by studies done with test beams of muons. The most probable value is in a rough agreement with what is expected for muons.

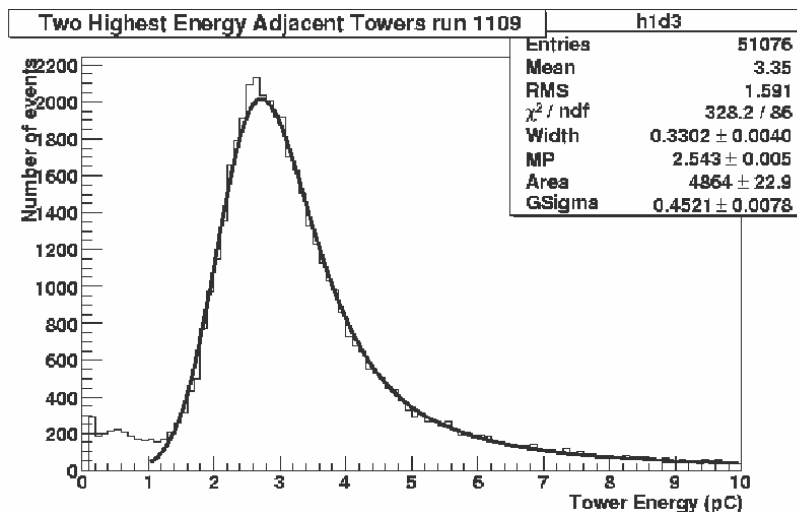


Figure 10. The energy spectrum in the two highest energetic towers of a TileCal module. The shape of the curve and the most probable value of the distribution are typical of muons in TileCal.

7. Conclusions

Following requirements of flexibility and robustness imposed by the busy working environment of the ATLAS cavern, a mobile data acquisition system was built to start the TileCal commissioning before its back-end electronics were ready for use. MobiDAQ proved its reliability both for debugging the front end electronics and for data acquisition of calibration runs. The achieved trigger rates and data bandwidth were adequate for the first phase of the TileCal commissioning. Finally, MobiDAQ has been used for the first ATLAS cosmics data taking in the pit.

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MobiDAQ has been only a piece in the mosaic of the commissioning of TileCal, which is a huge effort involving many physicist, technicians and funding Institutes. Without the support of the funding agencies, this work would not have been possible. We do not list all the persons and Institutes involved, but we take this opportunity to acknowledge and thank all of them.

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